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DISTANCE RELAYING SCHEME WITH MOV PROTECTED SERIES CAPACITOR

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Abstract – *Continuous increase in power demand leads the fast development in transmission line system. In order to meet the high demand for power transmission capacity, some power companies have installed series capacitor on power transmission line. This allows reduction in line impedance, thus resulting increased power transmission capacity. The series capacitor make sense because it is simple and could be installed 15 to 30% of the cost of installing a new line and provide the benefits of increased system capacity, reduced system losses and voltage regulation. Integration of the series capacitor in transmission line reactance adds certain complexities to the effective application of impedance based distance relays. The protective distance relays use impedance measurement in order to determine the location and presence of faults. The protective distance relays are fooled by series capacitor on the line when the presence or absence of capacitor in fault loop is unknown. In such condition distance relay overreach if fault in second zone or it may be reverse reach if fault in first zone.*

Keywords – *Parallel power gap; MOV protection; Operating characteristic of MOV; Transient fault analysis; MATLAB*

I. INTRODUCTION

Integration of the series compensation in transmission line makes the protection complex due to the abrupt changes in line parameters at the point of series compensation. This will lead to change in apparent impedance measured by the relays. Due to this there are several other problems like over voltage protection of series capacitor, voltage and current inversion etc. take place.

In the protection of series capacitors, the use of Metal Oxide Varistors (MOV) has become common practice. These devices protect the capacitors by ensuring that the voltage across the capacitor does not exceed a certain threshold as might occur during high current faults. The overvoltage protection of series capacitors slow down the operation of relay so that the capacitor protection system in use will have time to operate and remove the capacitor from service. Then the traditional distance relay (mho) will function properly [1].

II. PROTECTIVE EQUIPMENT OF SERIES CAPACITOR

As mentioned earlier, protective equipment is applied to the series capacitor to protect it from the excessive voltages which can occur during faults. This equipment takes one of two basic forms: a parallel power gap or a metal-oxide varistor (MOV).

A. PARALLEL POWER GAP

Up until the late 1970s, the power gap was the primary means of providing over voltage protection of the series capacitor. A simplified schematic of this system is shown in Figure. The gap provides protection for the capacitor by sparking over when the voltage across the capacitor exceeds a specific level. This level is known as the protective level. Usual values of protective level are 2.5 to 4.0 times normal operating voltage. A reactor is placed in series with the gap to limit the capacitor discharge current through the gap. Once current flow is initiated in the gap, a parallel bypass switch is closed to extinguish the arc in the gap. The bypass switch remains closed for a period sufficient to allow the gap to recover and then is opened automatically to reinsert the capacitor. A parallel power gap arrangement is shown in figure 1.

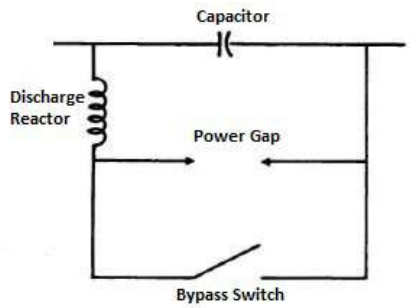


Figure 1. Parallel power gap

If the capacitor is used for transient stability improvement, then high speed reinsertion of the capacitor as well as high speed fault clearing is desirable. One of the 70 means for providing high speed insertion is the use of a vacuum gap in place of the air gap. The vacuum gap has excellent recovery voltage withstand which allows for high speed opening of the bypass switch.

Another system has achieved high speed reinsertion by extinguishing the arc by air blast rather than by closure of a parallel bypass switch. This system initiates air flow immediately upon detection of gap current. A drawback of this system is the potential for multiple spark-over of the gap for the same event which places added stress on the capacitor.

Due to the limitations in the ability to build large voltage gaps, banks which are protected by gaps are made up of multiple series/parallel segments. The sequential insertion of these segments can result in increased reinsertion transients and no simultaneous gap flashing.

B. METAL OXIDE VERISTORS (MOV)

A typical MOV-protected series capacitor arrangement is shown in Figure 8. The MOV protection is connected directly in parallel with the series capacitor and performs its function by holding the maximum capacitor voltage within the designed protective level [10] MOV conduction normally occurs only during faults because the capacitor protective level is usually specified above the maximum voltages expected during overload or swing conditions. The highly non-linear resistance characteristic of the MOV material makes it ideal for direct connection to the capacitor and for voltage limitation. The quantities indicated in Figure 2 are described below.

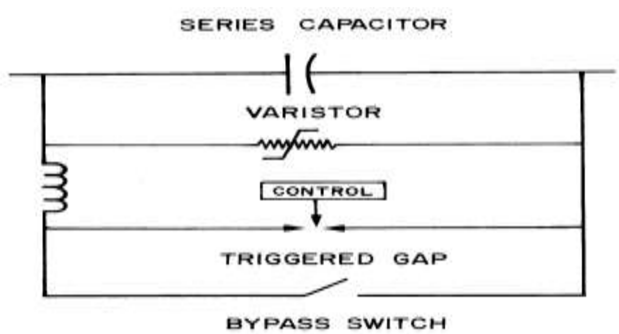


Figure 2. Typical circuit for MOV-protected series capacitors

MOV conduction results in absorbed energy which can be substantial for high-current faults like those near a series capacitor bank. The triggered gap is controlled by special circuitry and used to rapidly bypass the MOV and series capacitor if the absorbed energy reaches a pre-set value. The gap may also be fired if the rate of energy input exceeds a specified value. The triggered gap control and MOV energy capability are normally coordinated so that the gap may fire only during faults internal to its own line. The bypass switch inserts and removes the bank from service and also provides protection for failures or imbalances [5].

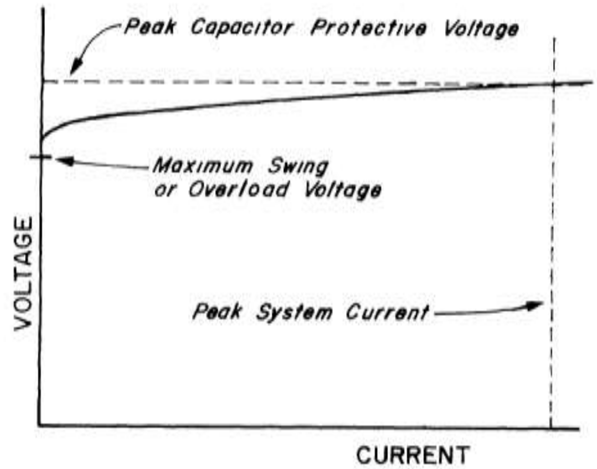


Figure 3. Basic characteristic of MOV protection

III. SIMULATION STUDIES

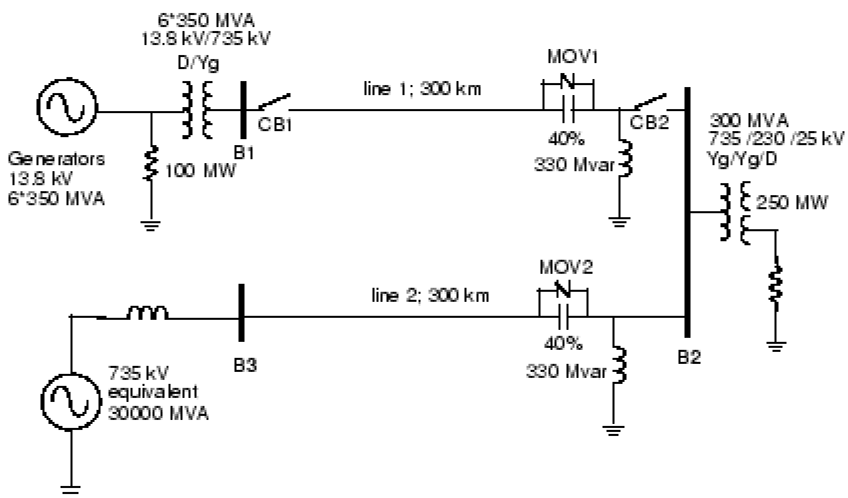


Figure 4. One line diagram of system

In order to achieving the operating characteristic of MOV, The transient fault studies are carried out using the well-known MATLAB (SIM POWER SYSTEMS BLOCKSET) program for performing various operation which is given below. The performance of the proposed technique is analyzed by considering a wide variation in fault resistance and fault location.

Table 1. System Parameters

Line Length	300 km
Voltage	735 kV
Compensation Degree	40%
Transmission line inductance	0.9337×10^{-3} Henry / km
Transmission line capacitance	12.74×10^{-9} farad / km
MOVs Reference .Current	2 kA
MOVs Protection Voltage	298.7 kV
Load	250 MW
System Frequency	60 Hz
Sampling Frequency	2000 kHz

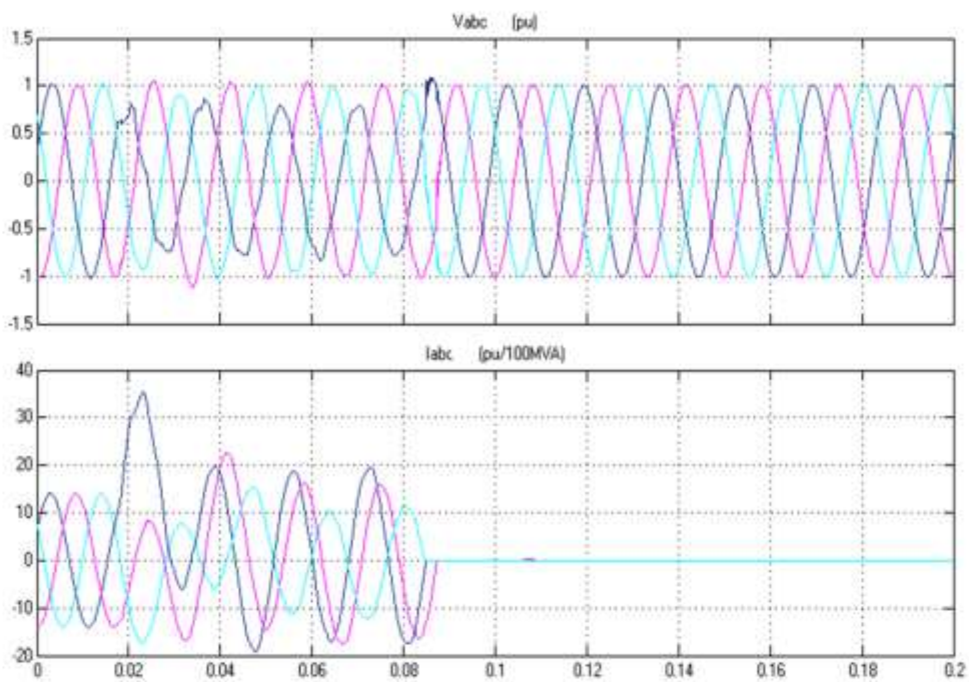
The fault is applied on line side of the capacitor bank. A line to ground fault is applied on phase at t = 1 cycle. The circuit breaker are initially closed are then open at t = 5 cycles. Simulating a fault detection and opening time is of 4 cycles. The fault is eliminated at t = 6 cycles, one cycle after the line opening. To test the suggested scheme the simulation studies have been carried out under wide variation of fault resistance and fault locations. The different values of fault type, fault resistance, which have been chosen for this study, are as follows: Table shows the simulation parameter.
Fault Type: R-G
Fault resistance: 0.001, 10 ohm

Table 2. Simulation Parameters

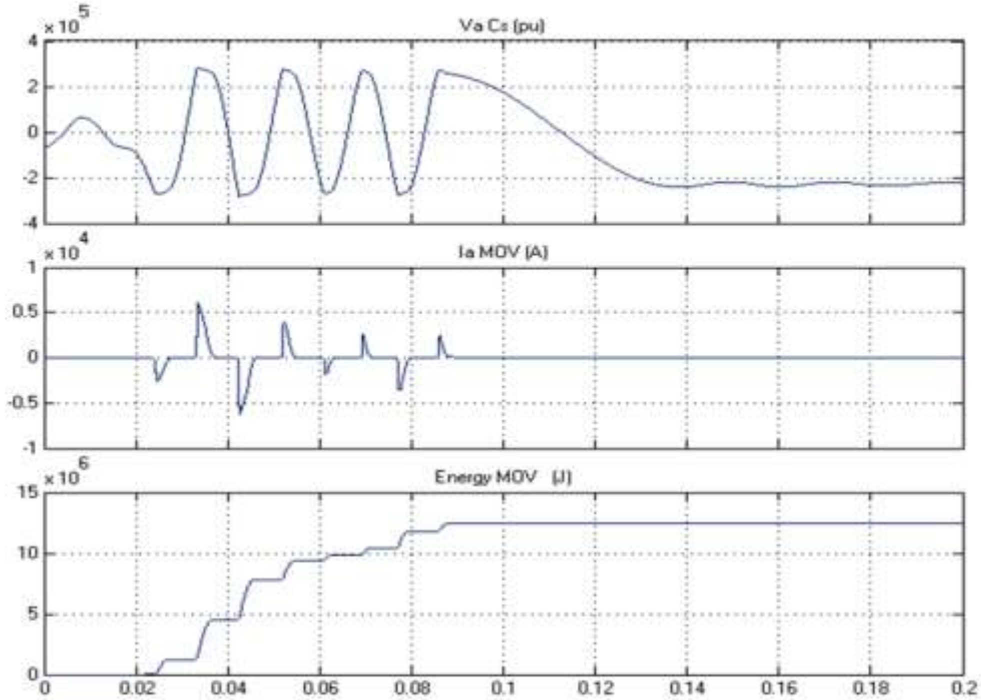
Simulation Time	0.12 sec (Six Cycle)
Sampling Frequency	2000 kHz
Simulation Starts	T=0 Sec
Fault is Applied at	T=0.02 Sec
Fault is removed at	T=0.12 sec

IV. WAVEFORM ANALYSIS

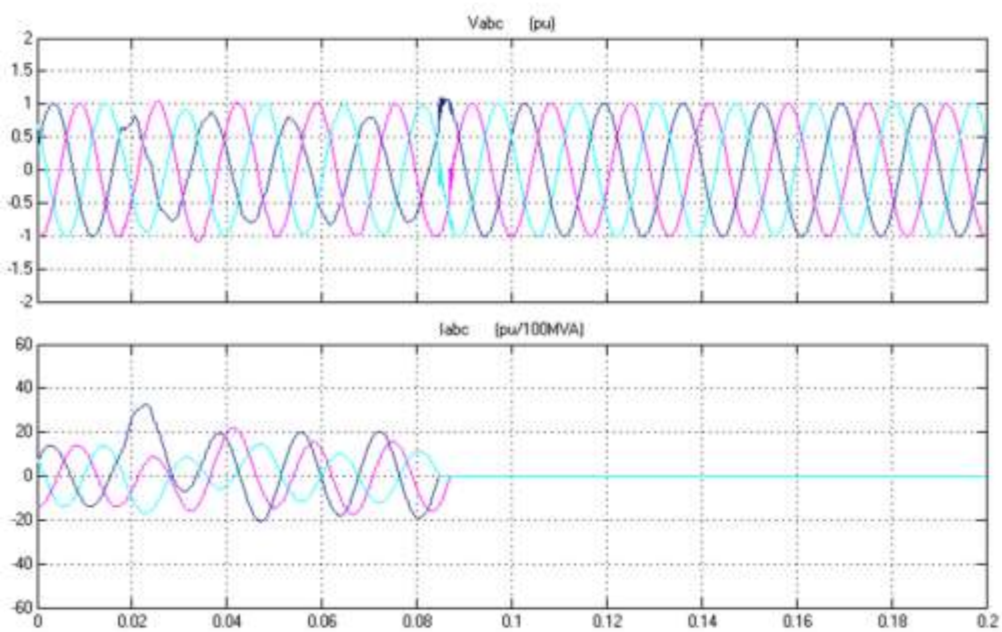
A. R-G FAULT FOR 40% COMPENSATION, FAULT RESISTANCE 0.001 OHM



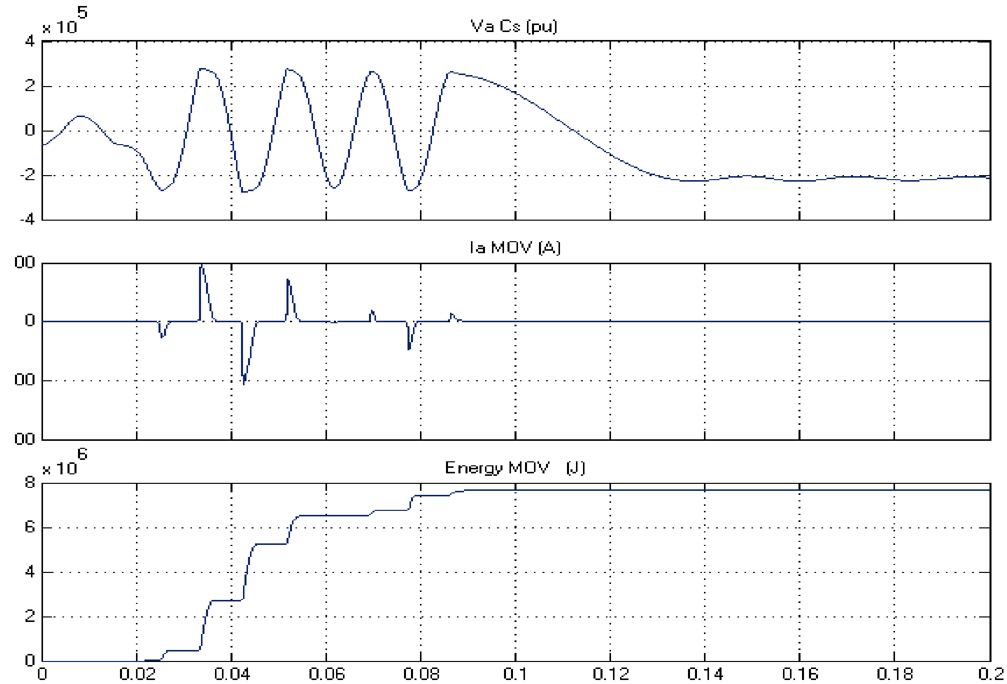
B. ACROSS MOV R-G FAULT FOR 40% COMPENSATION, FAULT RESISTANCE 0.001 OHM



C. R-G FAULT FOR 40% COMPENSATION, FAULT RESISTANCE 10 OHM



D. ACROSS MOV R-G FAULT FOR 40% COMPENSATION, FAULT RESISTANCE 10 OHM



V. CONCLUSION

To increase the transmission capacity given transmission line is series compensated by capacitor representing 40% of the line reactance. Line is also shunt compensated by a 330-Mvar shunt reactance.

The fault is applied on the line side of the capacitor bank. Simulation starts in steady state. At the t = 1 cycle, a line to ground fault is applied kept fault resistance 0.001 and 10. During the fault MOV conducts at every half cycle and the energy dissipated in the MOV builds up to 13 MJ. At t = 5 cycles the line protection relays open breakers and the energy stays constant at 13 MJ. As the maximum energy does not exceed the 30 MJ threshold level, the gap is not fired. At the breaker opening, the fault current drop to a small value and series capacitance starts to discharge through the fault and shunt reactance. The fault current extinguishes at the first zero crossing after the opening order given to the fault breaker (t = 6 cycles) then the series capacitor stops discharging and its voltage oscillates around 230 KV.

We can also study three phase to ground fault applied to the system with the 0.001 and 10 ohms of fault resistance. Here, during this fault the energy dissipated in the MOV builds up faster than in the case of a line to ground fault. The energy reaches the 30 MJ threshold level after three cycles, one cycle before the opening of line breaker. As a result, the gap is fired and the capacitor voltage quickly discharges to zero through damping circuit.

Here, the simulation study has been analysed for LG fault and for 0.001 and 10 ohms are taken as fault resistance and 40% compensation. Here one thing we observed is that energy across MOV build up faster than 40% compensation for same fault resistance for various kind of faults.

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